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Hydrogen and Helium Excitation in the Chromosphere and Chromospheric Flares.

V. L. Kirin, V. L. Sobolev.

Spectroscopic investigations of flares, made in recent years, show that the nature of excitation of hydrogen and helium atoms is different in different flares. While the appearance of hydrogen emission is typical of flares, the appearance of helium lines (more frequently in absorption) is not necessarily accompanied even by comparatively bright flares of importance 2. Even more so, as is shown by observations made at Pulkovo during 1956-1958, absorption in D_2 usually does not coincide with the region of maximum flare and can exist without a flare being present. In this respect observations of spectra of limb flares are of special interest. The observations made by Kirin (1) at Sacramento Peak of the limb flare of June 24, 1956, showed that there was a somewhat anomalous distribution of intensity in the emission of the lines $\text{He}^+ 4686$ and $\text{He} 4471, 4713, 4922$ and 6678 . On April 29, 1958 we were also able to photograph a limb flare in a comparatively wide spectral region, which showed the lines $\text{He} 4472$ and 4713 in emission. We were not able to detect any traces of $\text{He}^+ 4686$. Now there can hardly be any doubt that the hydrogen lines and those of neutral and ionized helium appear under different physical conditions in different parts of the flare. These conditions may or may not be present in the different flares.

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Recently we proposed a model of the chromosphere (2), consisting of numerous small filaments with temperatures and densities varying within wide limits. These filaments can conditionally be divided into four groups: 1) the coldest "metallic" filaments which lead to the appearance of lines of neutral and often ionized metals, with a temperature of not more than 6600° , 2) warmer "hydrogen" filaments, in which the lines of the Balmer series reach maximum (T 7000° - 8000°), 3) hot "helium" filaments, in which the lines of neutral helium reach maximum (T 25000°), 4) high temperature subcoronal flares with T $100\,000^{\circ}$ - $150\,000^{\circ}$, which cause the emission of the line $\text{He}^+ 4686$. Such a separation of the chromosphere into filaments with different temperatures as found by V. Krat and L. Pravduke (3) from the helium and hydrogen line profiles. Such a considerable non-homogeneity of the chromosphere evidently points to the absence of equilibrium states and the nature of the dynamics of motion of gaseous matter. Therefore the separate filaments must be short-living and the temperature and density of the gas must change rapidly with time. We also think that the chromospheric flares are composed of different filaments or layers with different temperatures and densities.

The density of the gas which causes hydrogen emission is evidently not so high as was assumed until only recently. Our observations do not show any evidence of a line broadening of the Balmer series from H_2 to H_{10} and H_{11} due to the Stark effect. There is also no noticeable self-reversal in these lines. The Fraunhofer spectrum (fig. 1) can be seen through the broad lines of the flare of 3 IX, 1957. However the

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hydrogen line profiles show that above the flare there is matter causing light scattering. This matter gives rise to absorption line profiles which are narrower than those of the emission lines of the flare and not broader than the ordinary chromospheric lines. Besides ejections from the flare, predominantly directed towards the photosphere, are observed in emission in the lines of hydrogen and ionized calcium H and K(4).

In order to interpret the behaviour of the helium lines we undertook a detailed investigation of the problem of helium equilibrium. Previously this problem had been considered by us (2) without accounting for photoionization from the level 2^3S . Now, taking this factor into account and also the role of impacts of the second type for the level 2^3S and other factors, we were able to compile precise tables for the occupation numbers of various states and for the computation of the first and second degree of helium ionization. Our tables differ somewhat from analogical tables published by Zirin (1). The new tables for the chromosphere qualitatively lead to the same results as the previous rough calculations(2). As the transitions between the higher levels, for low electron concentration n_e , are due mainly to photospheric radiation, the ratios of the line intensities $\frac{4472}{D_3}, \frac{4713}{D_3}, \frac{3889}{D_3}$ are practically constant for all T_e , being equal to :

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$$\frac{4472}{D_3} = 0.10, \quad \frac{4713}{D_3} = 0.01, \quad \frac{3889}{D_3} = 0.09$$

The flares show that the normal ratio of the intensities of the lines He 5876, 4472, 4713, 3889 can change only for high electron concentrations, not less than 10^{13} . This points to an extremely high density of the "helium" filaments of the flare observed by Zirina (1). In the majority of flares the density of these filaments must be lower. This in general does not contradict the results of E. Mustel and A. Severny (5). The exceptionally rare appearance of the line He⁺ 4686 in prominences and flares shows that it cannot be caused neither by coronal radiation nor by the ultraviolet radiation of the "helium" filaments themselves. It appears only in subcoronal filaments which can be formed during the transformation of chromospheric matter into coronal gas or vice versa.

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ON THE PROCESS OF FORMATION OF TERRESTRIAL PLANETS

V.A. Krat

Many cosmogonical theories on the origin of planets of the solar system meet with great difficulties when explaining the division of planets into terrestrial planets and Jovian planets (1,2). We showed (2, 3) that the hypothesis that the initial mass of the Sun was considerably larger than that at present, and that the Sun subsequently lost about 80% of this mass when passing through the giant stage, can satisfactorily explain the division of the planets into two groups.

Assuming, in accordance with all the authors of cosmogonical hypotheses, a homogeneous chemical composition of the gas-dust nebula at some time surrounding the Sun, we must suppose that, as a result of the action of some process (or mechanism), a large part of matter was removed from the zone of formation of terrestrial planets. At this time almost all the light elements and a part of the heavy elements, which did not form chemical compounds (inert gases), escaped. Elementary calculations show that if even 10-20% of all the mass of the planets was initially fine cosmical dust, then the gas-dust nebula must have been opaque for solar radiation already at distances of the order of kilometers. Therefore the difference of chemical composition of the planets cannot be explained by the penetration of solar radiation into the initial nebula. We therefore supposed that both groups of planets were formed successively at different epochs.

According to the data of Ambartsumian, Vorontsov-Velyaminov

and Krat (1, 3) the time during which the Sun could have been a B, Be type star or a red supergiant cannot exceed 10^7 years. The time of formation of large planets from the nebula should not be less than 10^7 years (1,4). Therefore during all the time of formation of planets, accompanied by the disintegration of the formed bodies, the concentration of dust was high. It is natural to assume that the inner part of the nebula, surrounding the Sun, from the very beginning was completely evaporated and no planets could have been formed from it. If we adopt $T = 1600^\circ K$ as the temperature of the evaporation of the dust particles and 2.5 AU as the width of the zone of formation of Jupiter (which was the first planet to be formed) it is easy to calculate that the initial mass of the Sun was 5.1 times larger than the present mass and the luminosity 670 times higher. With decreasing solar mass, as a result of the ejection of matter by the Sun, the luminosity decreased sharply and a possibility arose for the penetration of separate cometary-like condensations and clouds of dust into the inner zone. As the initial nebula should have captured $0.2 \cdot 10^{-3}$ parts of the gaseous mass ejected by the Sun, the final mass of matter of solar origin that was captured by the matter of the terrestrial planets was of the order of the Earth's mass. Under such conditions the angular moment per unit mass of that part of the nebula from which terrestrial planets were formed should have decreased. A second ring of matter was formed in the zone previously free of matter. According to calculations (2) the central part of this ring should have been at that distance from the Sun where the Earth was formed. The process of evaporation (similar to the process of evaporation of cometary nuclei) should have removed the gas component from the condensations and the dust of the inner ring. In the inner part of the ring, from which Venus and Mercury were formed, hydrogen, due to the dissociation of water vapour, was removed completely. In these planets (including the Earth) there was a deficiency in the nitrogen and carbon content. The inner gases escaped almost completely. In the direct vicinity of the Sun, inside the orbit of Mercury, no planets could have been formed. Evidently this is connected with that, that the process of formation of terrestrial planets ended before the Sun became a normal star of the main sequence, at the time when its mass was 1.5 times larger than it is

is now. It is possible that radioactive matter became a part of the terrestrial planets together with that part of the matter which was ejected by the Sun.

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SOME REMARKS ON THE PROTOPLANET FORMATION

E.L.Rouskol

The hypothesis on the origin of planets from massive proto-planets of cosmoical (solar) composition cannot satisfactorily explain the chemical composition of present planets, their rotation and other observational data.

It may be of interest to discuss some additional difficulties of that hypothesis. They are connected with properties which must be ascribed to the primary nebula in order that the latter could be broken up by gravitational instability into massive protoplanets.

The condensations formed in the nebula can exist in the nebula only if they resist against the tidal action of the central body by their own gravitation.

For the condensation of mass m self-gravitation along its axis r directed to the sun exceeds the solar tidal force at

$$\frac{\alpha Gm}{r^3} > \frac{2GM_{\odot}}{a^3} \quad (1)$$

where α is a coefficient depending on the form of the body. For a spherical condensation ($\alpha = 1$; $m = 4/3 \pi \rho r^3$) this corresponds to $\rho > 2\rho_*$, where $\rho_* = \frac{M_{\odot}}{4/3 \pi a^3}$ is the "expanded" solar density at a distance a .

For a flattened ellipsoid of rotation with semi-axes r, r, h ($\alpha \approx 2$; $m = 4/3 \pi \rho r^2 h$) this condition gives:

$$\rho > \rho_* \cdot \frac{r}{h} \quad (2)$$

In the case of condensation formed by the gravitational instability we can put its small semi-axis h roughly equal to the scale-height of the nebula H and identify its horizontal semi-axis r with the Jeans' critical wave length λ . According to Gurevich and Lebedinsky (1950) in the nebula with differential rotation around the central body

$$\frac{r}{h} \approx 13 \quad (3)$$

Because of such flattened form of condensations the usually accepted Roche density

$$\rho_R \approx 10\rho_* \quad (4)$$

must be considered as a minimum value.

As concerns the enormous protoplanets of G.P. Kuiper ($\frac{r}{h} \approx 10^2$) the condition (2) would lead to

$$\rho_R^{\text{Kuip}} > 10^2 \rho_*$$

The major part of the matter in the nebula of solar composition was in gaseous state because of great abundance of non condensed hydrogen and helium. If there were no appreciable sedimentation of solid particles toward the equatorial plane, then the dynamical behavior of the nebula was determined by gas at every z . In the case of laminar rotation of the nebula thermodynamical fluctuations of the density were negligibly small, therefore the necessary condition for the formation of condensations everywhere in the equatorial plane was:

$$\rho_0 > \rho_R \quad (5)$$

In the presence of turbulence (which is very doubtful for any Reynolds number as it was mentioned by H. Jeffreys in 1952 and shown in detail by Safronov and the author, 1956, 1957) the condition (5) must be satisfied too. Indeed, every density fluctuation created by turbulence would disperse, if it does not satisfy the two criteria of Jeans and of Roche. The scale of turbulence cannot exceed the scale-height of nebula H . According to (3) non dispersing density fluctuation must have horizontal dimensions $\lambda > 10H > 10h$ (that is to be greater than 10^2 of mean size eddies). At the same time it must have the Roche density ρ_R . Only if during the turbulent stage the density in the nebula approached ρ_R there would be some probability of crea-

ting stable fluctuations capable to grow up.

In the Kuiper's model of nebula with mass 0.05 - 0.10 the density in the median plane of nebula hardly reached a tenth of ρ_R . Therefore even if turbulence did exist in the nebula, its role in providing initial fluctuations for the protoplanets would be negligably small and the breaking up of such nebula into condensations would be impossible.

G.P. Kuiper's formulae for λ :

$$\lambda \geq 0,05 \left(\frac{\rho_R}{\rho} \right)^{1/2} a \quad (1951)$$

$$\lambda \geq 0,07 \left(\frac{\rho_R}{\rho} \right)^{1/2} \tau^{1/2} a \quad (1956)$$

seem to give the possibility of break-up of nebula at the density much lower than ρ_R . But they are obtained by formal introduction of ρ_R into formulae of Jeans and Ledoux for λ in non-rotating medium and really they do not take into account the Roche criterion. Therefore these formulae are not acceptable for the protoplanetary cloud.

Prof. Kuiper gives a reference to the paper of Chandrasekhar (1955) which shows the Jeans criterion to be unchanged in the presence of rotation. But Chandrasekhar's case is the rigid rotation of infinite medium without tidal forces of central mass and cannot be applicable to the solar nebula.

Let us calculate the mass of the nebula needed for the formation of gaseous protoplanets.

The mass of the nebula is:

$$M = \int_{a_0}^{a_n} 2\pi \sigma(a) da \quad (6)$$

The total mass per unit area $\sigma(a)$ in a flattened nebula with a given $\rho_c(a)$ can be obtained from an equation of the equilibrium in z - direction at a distance a from the sun:

$$-\frac{1}{\rho} \frac{dp}{dz} = \frac{GM_{\odot} z}{(a^2 + z^2)^{3/2}} + 4\pi G \int_0^z \rho dz \quad (7)$$

taking into account both solar and nebular forces of gravity in z - direction. Almost the whole mass of the nebula was an H I region and we can take it roughly isothermal in z - direction and put

$$\frac{dp}{dz} = \frac{RT}{\mu} \frac{d\rho}{dz} \quad (8)$$

We can also neglect z^2 with respect to a^2 . Then differentiating (7) we obtain a non linear equation of 2nd order which is soluble for $\frac{d\rho}{dz}$:

$$\frac{d\rho}{dz} = -\rho \sqrt{\frac{2\pi G \mu}{RT} (\rho_0 - \rho) + \frac{2GM_0}{RT_0^3} \ln \frac{\rho}{\rho_0}} \quad (9)$$

ρ_0 being the density in equatorial plane. Ledoux (1951) obtained a formula for $\rho(z)$ in non rotating flattened nebula; (9) is a generalisation of it for a rotating nebula.

The total mass per unit area is:

$$\sigma = 2 \int_0^{\infty} \rho dz = \sqrt{\frac{2RT\rho_0}{\pi G \mu}} \cdot J(y^*) \quad (10)$$

where $J(y^*)$ is a numerically calculated integral depending on the ratio $y^* = \frac{\rho}{\rho_0}$:

$$J(y^*) = \frac{1}{2} \int_0^1 \frac{dy}{\sqrt{1-y-\frac{1}{3} \ln y}}; \quad y = \frac{\rho}{\rho_0} \quad (11)$$

In Ledoux' case $J=1$; for the Roche density ($\frac{\rho}{\rho_0} = \frac{1}{10}$) $J=0.9$

The mass calculated for the case of Roche density (4) in the equatorial plane, $\bar{\mu}=2,4$ and the distributions of temperature accepted by G.P.Kuiper, is given in Table 1.

Table 1

The mass of the protoplanetary nebula expressed in solar masses

	Black body temp. $300^\circ K$ $T = \frac{300^\circ K}{\sqrt{2\pi\mu}}$	Kuiper 1951 $T = \frac{300^\circ K}{\sqrt{2\pi\mu}}$	Kuiper 1956 (approx.) $T = \text{const} = 25^\circ K$	Mass according to Kuiper	Mass of present planets
In limits of solar system $\alpha_0=0,3a_u; \alpha_n=40a_u$	2,2	1,4	1,0	0,05-0,1	$1,3 \cdot 10^{-3}$
In the zone of inner planets $\alpha_0=0,3a_u; \alpha_n=2a_u$	0,4	0,4	0,12	0,02	$6 \cdot 10^{-6}$

The mass of primary nebula must be very great. Even for very low temperatures it cannot be less than the solar mass. This is 30 times greater than the present mass of planetary system plus light elements. It is the first difficulty of the hypothesis on gaseous protoplanets.

Secondly, masses of condensations in such a nebula must be of the order of 10^{29} - 10^{30} g, i.e. comparable with great planets. There would be some tens or hundreds condensations in each planetary zone. The evolution of such massive and numerous condensations e.g. into a few small terrestrial planets seems to be impossible.

For the formation of extended condensations almost touching one another in opposition a mass of nebula of order of 10_6 is needed. But this is quite unreasonable.

At last a very violent factor is necessary for the removal of the great excess of matter from the solar system. The solar corpuscular radiation may be the only effective mechanism, as was shown by G.P. Kuiper (1953). With Biermann's value for the intensity of the corpuscular emission he obtained the desirable rate of dissipation of 0,1 e from the interplanetary space (the dissipation of a half of this amount from protoplanets being not calculated in detail). However the Biermann's value for the intensity of corpuscular emission is exaggerated by a factor of 10^4 - 10^5 as compared with the recent estimations:

Table 2

Intensity of solar corpuscular emission

Bierman (1951)	$8 \cdot 10^{22}$ g/year=0,12e	$/3 \cdot 10^9$ years
Van de Hulst (1950)	$5 \cdot 10^{17}$	
Kiepenheuer (195)	$1.5 \cdot 10^{18}$	
Mustel (1956)	$6 \cdot 10^{17}$	
Nikolsky (1956)	$9 \cdot 10^{17}$	

But even the Biermann's value would be insufficient for dissipation the mass actually needed for the gaseous protoplanets hypothesis. If we suppose the necessary activity of the sun in the past we get a much greater mass of the ancient sun (and of course of primary nebula) than its modern value which is not consistent with recent ideas on the solar evolution.

The difficulty with great masses of the nebula and of condensation does not exist in the case if only the layer of solid particles in the cloud was broken up into condensations (the process considered by Gurevitch and Lebedinsky). This can be possible after the sedimentation of solid condensate to the median plane through the gas. As it was shown by Safronov and the author, (1957), this sedimentation occurs in a sufficiently short time.

Such are the additional considerations against the hypothesis of massive protoplanets.

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ON THE PLANETARY DISTANCES AND MASSES

B.J.Levin

Prof. O.J.Schmidt has shown that the growth of planets by sweeping up smaller bodies includes some competition between the neighbouring planets, which regulates the distances between the orbits.

If two growing planets (planetary embryos) acquire orbits too close to each other they will soon sweep up bodies moving between these orbits. The further growth of the inner embryo of the pair will proceed mainly as a result of accumulation of bodies moving closer to the sun and having smaller specific angular momentum. Therefore the specific angular momentum of the embryo, as well as the radius of its orbit, will decrease. The outer embryo of our pair will add mainly the bodies of greater specific angular momentum and the radius of its orbit will increase. The orbits will shift apart until they are stopped by the competition with their next neighbours.

Deducing in the simplest way the law of planetary distances established by this competition process prof.Schmidt suggested that each planet had a fixed feeding zone with sharp boundaries. This leads to a formula

$$\sqrt{R_n} - \sqrt{R_{n-1}} = \text{const} = b \quad \text{or} \quad \sqrt{R_n} = a + bn$$

which represent fairly well the distances of terrestrial planets and of distant planets. In the latter case the constant b is 5 times greater than for the terrestrial planets:

It is clear that the width of the feeding zones is closely connected with the orbit eccentricities of the swept up bodies.

In 1950 Gurewitch and Lebedinsky had shown that these bodies were formed from the dust component of the circumsolar proto-planetary cloud. Therefore they moved at first along nearly circular orbits lying in the plane of the flat disk from which they originated. Only later became their orbits more and more elongated having inclined under the influence of their mutual gravitational attraction. Although a quantitative treatment of this process is very difficult, some qualitative conclusions can be made.

Perturbations occurred more frequently in the denser part of the swarm. Therefore the dispersion of eccentricities was rapidly increasing and the massive planets accumulating there acquired wide feeding zones. It explains why the outer planets are situated at greater distances from one another than the small terrestrial planets. It explains also the correlation between the masses and the distances found by Kuiper not only for planets, but also for regular satellites.

The planetary embryos being the largest bodies in their respective zones produced the largest perturbations in the motion of other bodies. For terrestrial planets even a relatively close encounters produced only small orbital changes. This provided a sufficient width of the feeding zones, but the ejection of asteroidal bodies into other zones played an unimportant role. In the course of time the overwhelming part of bodies from each zone were accumulated into the corresponding planet^{x)}. The masses of the terrestrial planets are predetermined mainly by the mass of solid bodies and particles present in the zone of their formation.

The giant planets are more massive and are situated far from the sun, so that its gravitation is small in their regions. Therefore bodies passing a growing planet at a distance of its several radii could change their motion from nearly circular to nearly parabolic or even hyperbolic ones.

If we take the velocity of escape from the surface of a given planet as indices of its perturbing capacity we see (table I) that for more distant planets of this group these capacities are about the same as that for Jupiter, in spite of their smaller masses. Considering the increase of energy instead of the velocity a similar result is obtained.

x) The small mass of Mars is probably due to its voracious neighbour - the Jupiter.

Table I

Planet	ν_c	$\nu_p - \nu_c$	ν_c^2	$\nu_p^2 - \nu_c^2$
Earth	11,3	12,4	125	900
Jupiter	60	5,4	3600	170
Saturn	36	4,0	1300	92
Uranus	21	2,8	440	46
Neptun	23	2,4	530	30

When the effective cross-section for large perturbations became many times greater, than the effective cross section for direct collisions with the surface, further growth of a planet was stopped, because the bodies that had to be swept up were ejected from the feeding zone. The further from the sun the smaller mass is needed for such ejection. Accordingly the planetary masses decrease from Jupiter outwards. These are the greatest limiting masses for planets formed by the sweeping up process independent on the initial mass of the solid matter in their feeding zones.

The calculations by V.S. Safronov have shown that if the mass of solid bodies and particles distributed in the feeding zones of Uranus and Neptune equalled the present masses of these planets, their growth would require enormous periods of time of the order of $10^{11} - 10^{12}$ years. Only if the initial mass had been greater for several orders of magnitude, could the accumulation be reached in an acceptable period of time. Excessive mass probably existed also in the feeding zones of Jupiter and Saturn.

The bodies and particles in the region of giant planets had icy composition. Their ejection on nearly parabolic orbits must be the formation process of the Oort's cloud of comets.

V.S.Safronov.

The accumulation of terrestrial planets.

1. Basing on the idea of the dominant role of solid matter in the process of planet formation we have recently studied the mechanism of planet accumulation. The formation of bodies from which the planets have grown is considered as a result of damping of irregular motions in the protoplanetary gas-dust cloud, of separation of dust from gas (sedimentation of solid particles towards the equatorial plane) and of break-up of a flat dust disc into numerous condensations due to gravitational instability. The condensations had originally rotated (preferably in direct sense having in average the positive angular momentum of condensed region) which prevented their contraction. However, as it was shown by the author (1958b) the collection of condensations was accompanied only by very slow increase of angular momentum and caused rapid contraction. Increase of the mass of condensation by a factor of several tens (to about 10^{24} - 10^{25} g at Jupiter's distance and $2 \cdot 10^{18}$ g in the earth's zone) was sufficient to transform the condensation into a solid body with the density of the order of a unity. There are no grounds to suppose the existence of "secondary condensations" with different features of growth introduced by Gurevitch and Lebedinsky.

Critical density could be attained in the disc only if random velocities were small, less than $v_{cr} = 6 \sqrt{\frac{2\pi G}{M_0}}$ where G is the mass per unit area of the disc. At the distance of the earth from the sun v_{cr} is a few cm/sec and at the Jupiter's distance $\sim 2 \cdot 10^2$ cm/sec. One can hardly imagine the ideal symmetry of the cloud and absolute absence of even smallest irregular motions. Hence it was possible that in the inner region of the cloud gravitational instability did not occur at all and bodies accumulated directly from particles.

Thus the solid condensate of the protoplanetary cloud had transformed into a swarm of bodies at the early stage of its evolution. The swarm, initially very flat, gradually thickened while the bodies grew and their mutual gravitational perturbations increased.

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2. The growth of planet "embryos" as a result of fall on them of bodies and particles was studied by O.J.Schmidt (1945) and further by the author (1954, 1958a). The rate of the mass increase can be written in the form

$$\frac{dm}{dt} = r\pi z_e^2 \rho v = \frac{4\pi r}{P} z_e^2 \sigma(t) \quad (1)$$

where m and z_e are the mass and effective radius of the embryo, P - period of the revolution around the sun, r - probability of "coagulation" at a collision ($r=1$ was usually assumed), v - velocity of bodies and particles with respect to the embryo.

One may consider that in the earth's zone total mass of solid matter remained constant. Then the mass per unit area is

$$\sigma(t) = \sigma_0 \left(1 - \frac{m}{Q}\right) \quad (2)$$

where Q is the present mass of the planet. It can be shown that small particles were swept out rapidly by numerous larger bodies and were thus not important for the growth of the embryo. Hence we can take as z_e the collision radius $z_e = 2\sqrt{1 + \frac{2\theta}{\theta_0}}$. The relative velocities of bodies were due to gravitational perturbations at their encounters with more massive bodies. The value of v taken by Gurevitch and Lebedinsky has the simple meaning - the equality of double kinetic energy v^2 of relative motions of bodies to the potential energy of their interaction at the closest encounter $Gm/2z$. This gives right dependance of v on mass and radius of the embryo, but the factors diminishing relative velocities being not taken into account, the true value of v must be something less. We have taken $v^2 = \frac{Gm}{\theta z}$ where θ equals several units. Then $z_e^2 = (1 + 2\theta)z^2$ and one can find $m(t)$ from (1). Some uncertainty is introduced by θ which is not exactly known. Calculations (1958a) at $\sigma_0 = 10 \text{ g/cm}^2$ lead to the following results. The earth has reached 99% of its present mass during 10^8 years if $\theta = 3$ and during $4 \cdot 10^7$ years if $\theta = 10$. (O.J.Schmidt obtained much slower rate of the growth as he assumed the velocities to be high and took the geometrical radius of the embryo). The surface temperature of the growing earth due to the shocks of falling bodies was low - less than $350 - 400^\circ \text{K}$ even at

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the maximum bombardment. (In the previous paper (1954) the calculations were made for several constant values of V . New results with gradually increasing V correspond to the lower values of temperature obtained earlier). The inner parts of the growing earth were heated due to the radioactivity and to the contraction under the pressure of newly layers. The temperature was maximal at the centre of the earth, 1000°K being reached to the end of the first 10^8 years. The temperature gradient was about -0.03 per km.

As the meteoritic matter falling now on the earth is not the remnant of matter of the earth' "feeding" zone, the rate of its infall cannot be used for the determination of the age of the earth by the formula (1).

The heating of the Jupiter's surface during its growth was greater and exceeded 1000°K . This may explain the higher densities of Jupiter's inner satellites.

The outer planets; Uranus, Neptune and Pluto grew much slower because of greater P and lesser σ in (1). They could reach their present masses in the cosmogonic time only if the initial density of matter in their region was considerably higher than the density calculated from the present mass of the planets. A similar conclusion is also made in the theory of the origin of comets, cometary cloud being supposed as a product of ejection of bodies from the outer zone by massive embryos.

3. The breaking of bodies at their collisions prevented the complete sweeping out of small particles by bodies and maintained the opacity of the swarm for a longer time. The disruptions led to great differences in sizes of bodies. That in turn weakened the destructivity of collisions which are more dangerous for bodies of equal masses. For the most massive embryos the collisions with other bodies were the least destructive, the kinetic energy of the shock exceeding only slightly the gravitational energy on the surface of the embryo ($v^2/v_e^2 = 1/20 \ll 1$). At collisions a large part of energy transforms into heat. Hence after the collision a greater part of broken material should return to the embryo.

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One can believe therefore that the disruptions did not change the mean features of the process of embryo growth. Some retardation of growth was partly compensated by the decrease of relative velocities of bodies (increase of θ) that accelerated the growth. The uncertainty of the product $\gamma(1+2\theta)$ in (1) is not more than that of θ and the overestimation of the rate of growth when taking $\gamma=1$ is probably wholly compensated because of somewhat underestimated value of θ .

One can roughly estimate the amount of matter underwent disruptions during the whole accumulation process. For the simplest case when the swarm consist of equal bodies the part

p of their total mass would pass through disruptions: $p \approx 1 - (\frac{m_0}{m})^\beta$, where β - probability of break-up at a collision. Disruptions would probably begin at $m_0 \sim 10^{18}$ g. Taking for example $\beta = 0.1$ and $m_0/m = 10^{-8}$ we find $p \approx 0.7$. Therefore the larger part of the total mass of bodies has passed through disruptions. Repeated break-ups and collections of the bodies of different masses, internal temperatures and pressures have led to the formation of various complicate structures similar to those we observe in meteorites.

The study of the accumulation process with account of break-ups of collided bodies requires the elaboration of the mechanism of break-ups itself and also of the knowledge of more exact value of relative velocities. Then it would be possible to find in particular the distribution function of body sizes and to investigate its changing with time.

4. The full analysis of the accumulation process must also take into account the "assymmetry" of shocks of bodies falling on the embryo that lead to the planet rotation. Increase of rotational momentum of the embryo may be written in the form

$$\Delta K = \alpha v r \Delta m.$$

The simplest assumption about the constancy of α at $v \sim \sqrt{v_0}$ leads to $K \sim m^{3/2}$ and $\omega \approx \text{const}$, i.e. to the approximate equality of the periods of rotation of the planets, which is in a rough agreement with the facts. It would be desirable to find α theoretically, from the statistical examination of the three body problem, and compare it with the value corresponding to the present planetary rotation.

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Quantitative agreement would be a good criterion of our conceptions.

5. The process of growth of the major planets was complicated by the following factors:

- a) Dissipation of matter from this region.
- b) Accretion of gas by the most massive embryos.
- c) Possible solidification of a part of hydrogen.

It would be very desirable to ascertain whether the temperature in the outer part of the protoplanetary cloud could be as low as $4 - 8^{\circ}\text{K}$ which is necessary according to Urey (1958) for an effective condensation of hydrogen (and even lower, as far as the Roche density was probably not reached in the gaseous component of the cloud).

Solution of these questions is necessary for approaching a quantitative analysis of the accumulation process of major planets.

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THE SOVIET EXPLORATION OF THE IONOSPHERE BY MEANS
OF ROCKET AND SPUTNIKS.

S u m m a r y

1. A group of Soviet scientists since 1954 have been investigating the ionosphere by means of very high frequency dispersion interferometers installed at the rockets. The distribution of electron concentration up to the height of 475 km has been obtained. It has been found out that above the maximum of F_2 -layer at the height of 290 km to 475 km the electron concentration varies from $1.8 \cdot 10^6$ to $1.0 \cdot 10^6$ electron cm^{-3} respectively. Under the maximum of F_2 -layer it has been found no strongly pronounced layers of the ionosphere. In general, ionization continuously increases from the bottom up to the maximum of the F_2 -layer with many small maxima. The F -region and the maximum of the F_2 -layer are located 50-150 km lower than the results of usual ionospheric probing show.

2. A.N. Kazantsev, Y.L. Alpert and oth. have investigated the intensity level of radio signals of the Soutniks. They have found out that F -layer absorbs the radio waves of ultra short wave range. It has been discovered that the sputnik's signals (20 mc) are received at a distance of tens of thousand km; that indicated to some unusual ways of radio wave propagation from the ionosphere above its ionization maximum. The scientists have investigated the phenomena of the 'radiodawn' and 'radio set'. They have managed to receive pure observations of these phenomena only in a few cases out of many thousand. There exists an idea that according to a certain regularity of the electron concentration with height it is possible to make some estimations of the electron concentration above the maximum of the F -region. Such estimations are of uncertain character. The investigations of the intensity level of the sputnik's radio

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signals give a qualitative indication to a slow decrease of the electron concentration above the maximum of the F_2 - layer.

3. Another group of the research workers has conducted the investigation of the ionosphere by ion traps and probe characteristics, the equipment borne by the third sputnik. At the height of 242 km the density of positive ions $5.2 \cdot 10^5 \text{ cm}^{-3}$ and the electron temperature of 7000°K have been recorded during the day time. At the height of 795 km at the same day the density of ions $1.8 \cdot 10^5 \text{ cm}^{-3}$ and the electron temperature higher than 15000°K have been registered.

4. The indicated investigations show that the ionosphere model constructed according to the data of usual ionospheric probing needs to be revised. There exists a large scale height for ionized particles that well agrees with that of the upper atmosphere resulting from the observations of retarding the sputniks. The increase of the electron temperature with height as well as its increase in gaseous discharge can be explained by the increase of the length of the electron free run, the electromagnetic fields being present in the ionosphere. Such fields can arise in the process of circulation of the electro-conductive upper atmosphere in the magnetic field of the Earth when it is affected by the magnetic fields freezed into the corpuscule fluxes of the Sun and interplanetary gas passing by the Earth.

THE ARCTIC SCIENTIFIC RESEARCH INSTITUTE

"ON THE METHODIC PROBLEMS CONNECTED WITH COMPARING
MAGNETIC DISTURBANCES OF THE ARCTIC AND ANTARCTIC"

By A.P. NICOLSKI

About 20 magnetic observatories will be active in the Antarctic in the course of the International Geophysical Year. In analyzing the observational data on magnetic disturbances necessity arises of comparing magnetograms coming from the stations in the Arctic and the Antarctic. The problem will necessarily stand out as to which of the stations in the Antarctic can be most profitably compared with suitable stations in the Arctic.

It is clear that the choice of stations based on the close proximity of their geographical coordinates could not be considered since peculiarities of magnetic disturbances are dependent mainly on their geomagnetic latitudes. Yet choosing comparable stations merely on the grounds that their geomagnetic latitudes are close may also prove to be unsatisfactory for it is apparent that longitudinal effects have their definite part in the phenomenon of magnetic disturbance. Attempts, for example, at comparing magnetograms from station "Mirny" ($\psi = 66.6^\circ$; $\lambda = 93.1^\circ$ E; $\phi = 77.0^\circ$) with those from "Tikhaya Bay" ($\psi = 80.3^\circ$; $\lambda = 52.8^\circ$ E; $\phi = 71.5^\circ$) have not proved successful though their geomagnetic coordinates are close comparatively speaking.

The conclusion drawn by the Arctic Institute from their study of magnetic disturbances permits of suggesting certain recommendations in this respect.

It has been pointed out (1) that the isochrons of the morning maximum of magnetic disturbances in the Arctic represent a system of spirals originating at the pole of uniform magnetization and developing clockwise, fig. 1. We deem it expedient to apply this law in order to determine which stations in the Arctic and Antarctic could be suggested as comparable, at least in the sense of comparing the magnetic disturbances producing the morning maximum.

It follows from Störmer's theory that in the Antarctic the isochrons-spirals of the corpuscle precipitation are to develop counter clockwise since, judging by the observations conducted in the Arctic, the morning maximum seem to be caused by positive particles-the protons, by all probability. On the basis of the observational data obtained at the stations in the Antarctic and quoted by Stagg in his work (2).

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Cape Evans ($\Psi = 77.6^\circ$; $\lambda = 166.4^\circ\text{E}$; $\Phi = 78.9^\circ$),
Cape Lenise ($\Psi = 67.6^\circ$; $\lambda = 142.5^\circ\text{E}$; $\Phi = 75.5^\circ$) and
Gauss Land ($\Psi = 61.6^\circ$; $\lambda = 89.5^\circ\text{E}$; $\Phi = 76.1^\circ$)

we have plotted a system of isochrons of the Antarctic symmetric-
al with those of the Arctic.

At present, P.K. Senko had completed his treatment of the
magnetic observation data obtained at Station "Mirny" in 1956-
1957. It has been established that the time of setting in of
the morning maximum of magnetic disturbances at this station
coincides to an hour with the isochron for the region of station
"Mirny", drawn up earlier at the time when its observational
results had not yet been made available. This proves that the
isochrons of the setting in of the magnetic disturbance morning
maximum for the Antarctic are apparently true.

Fig.2 shows a map of the Antarctic on which the isochrons
of the morning maximum of magnetic disturbances have been plotted.
There are also, marked with dots, the 30 Antarctic stations at
which it is proposed to conduct magnetic observations during the
International Geophysical Year (the names of these stations and
their coordinates are given in the attached list).

Should we take the maps of isochrons for the Arctic and
Antarctic as a starting point then, magnetograms from station
"Mirny" should apparently be best compared with those of the
stations situated on either the north and west coast of Iceland
or on the eastern coast of Greenland, between 65 and 75° Geo-
graphical Latitude. Correspondingly, comparing other stations
one should proceed from the viewpoint of their location in
relation to the isochrons of the morning maximum of magnetic
disturbances.

At the present time, when the observation data from the
Antarctic magnetic stations that work to the program of the
International Geophysical Year, have partly been already
treated it is very essential to ascertain how close is the
correspondence of the observational data with the isochrons
drawn up for the Antarctic.

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V.A.ALEXANDROV, M.I.PUDOVKIN, V.M.YANOVSKY.

THE MAGNETIC FIELD OF MAGNETIC DISTURBANCES IN THE
ARCTIC AND ANTARCTICA.

1. The problem of distributing the field of magnetic disturbances on the Earth's surface has not been solved until now due to the lack of the experimental data because the existing network of magnetic observations offers no opportunity of setting up such a problem. That is why the only way out is the organization of temporal stations for recording magnetic disturbances within a short period of time on a comparatively small area.

2. The attempt to set up such stations were made by the Research Institute of the Arctic Geology which has been conducting observations of magnetic variations during the summer months of 1953-1957 at 6 or 7 stations located in the north-western part of Siberia.

The stations were situated 150-200 km. from each other and operated annually from March to September.

3. These observation results together with those of the adjoining magnetic observatories showed that not only each station had its own variations of magnetic disturbances but also each disturbance had its own distribution of the field. These facts indicate that the source of the disturbances is distinctly limited and mobile.

4. The preliminary processing of the observations comprised the determination of the absolute values of the variations of the vertical and horizontal components of any storm by data of each station and plotting them on the maps with different moments of time to construct isolines for the given moment of time plotting the vectors of the horizontal component on the latter.

5. These maps make it possible to establish the following facts:

a) the epicentres of the disturbances are localized between the meridians of the Tixi Bay and Mopikar frequently lowering below the Polar Circle,

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b) nearly at all the periods of the day the current disturbances show that the principal direction of the maximum gradient of field intensity is meridional which testifies to the stretch of current lines in the ionosphere in a latitudinal direction.

c) as a rule, the isolines of the horizontal component embrace epicentres of the vertical component of both signs being of a maximum value on the zero isoline of the vertical component; this also confirms the latitudinal character of the current lines.

6. The comparison of magnetic and ionospheric disturbances from observations at the Mirny station in Antarctica made in May-August 1957 showed that magnetic disturbances, especially those with the amplitude of the vertical component being much lesser than that of the horizontal one, are caused by the sporadic layer E of a screen type.

7. As the behaviour of the ionosphere in Antarctica is governed by the same laws as in the Arctic despite some peculiarities there are more grounds to assume that the source of magnetic disturbances on polar regions of the Northern Hemisphere is the layer E also.